Central Advisory Water Committee

Sub-Committee on Information on Water Resources

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CENTRAL ADVISORY WATER COMMITTEE
SUB-COMMITTEE ON INFORMATION ON WATER RESOURCES

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CONTENTS

Paragraph

I. APPOINTMENT
- Terms of Reference 1
- Co-options and assessors 2

II. INTRODUCTION
- The problem stated 3–8

III. CURRENT ACTIVITIES
- Classification 9
- Rainfall 10
- Evaporation 11–16
- Surface Water 17–23
- Ground Water 24–26

IV. THE ADDITIONAL WORK NEEDED
- Rainfall 27–40
- Surface Water—Quantity 41–48
- Surface Water—Quality 49–52
- Ground Water—Quantity 53–57
- Ground Water—Quality 58

V. COLLECTION, INTERPRETATION, CORRELATION AND PUBLICATION OF INFORMATION
- Hydrological research 59
- Collection of Information 60
- Interpretation and Correlation of Information . . . 61–62
- Publication of Information 63

VI. CONCLUSIONS AND RECOMMENDATIONS 64–68

APPENDIX I. Principal Official Publications.

APPENDIX II. List of authorities and organisations from which evidence was received.

REPORT TO THE
CENTRAL ADVISORY WATER COMMITTEE

I. APPOINTMENT

1. We were appointed by the Central Advisory Water Committee on 31st October, 1955, as a Sub-Committee with the following terms of reference:

> "(i) to review the current activities which contribute to our knowledge of the nation's water resources;
>
> (ii) to define the additional work needed to make a balanced survey of the quantity and quality of surface and underground water available for domestic, industrial and agricultural use;
>
> (iii) to advise on ways of collecting and interpreting the necessary information, correlating it with information from other sources and publishing it."

2. Mr. A. Atkinson, Mr. J. S. Evans, Mr. J. D. Peattie, Mr. H. G. Ramsay, Mr. J. I. Taylor and Mr. E. W. Wells accepted invitations to become co-opted members. Mr. Evans resigned in 1956 and was succeeded by Dr. C. J. Jackson; Mr. Peattie resigned in February, 1957, on his retirement from the Central Electricity Generating Board, and was succeeded by Mr. D. Clark. We also had the advice of assessors appointed by the Ministry of Agriculture, Fisheries and Food, the Meteorological Office, the Department of Scientific and Industrial Research and the Ministry of Housing and Local Government. Mr. R. H. Cuthbertson acted as observer for the Department of Health for Scotland. In addition to information provided by the assessors, who have contributed papers and attended our meetings, we have received written evidence from a number of organisations on particular aspects of our terms of reference. Our report covers England and Wales.

II. INTRODUCTION

3. The Inland Water Survey Committee, in their first annual report dated 1935–36, stated that

> "An adequate survey . . . involves systematic measurement over long periods of both overground and underground water, the collection and recording of the measurements in a uniform manner and the publication of the records together with rainfall statistics so that the relation between the precipitation of water, the run-off, underground storage, and losses due to absorption and evaporation may be ascertained.
>
> For overground water, the problem is largely one of securing the provision at suitable points of the measuring apparatus best adapted to the local conditions and of making the calculations from which accurate records of the discharge may be obtained. In view of the frequent changes in the flow of water passing the gauging points, continuous recording will in most cases be essential.
>
> Underground water presents a complex and difficult problem and the survey in this case is largely a matter of research—the observation of a great variety of data and drawing inferences from them."

4. A variety of bodies and interests need, and some collect, information about water resources. They include:

(*a*) Water supply;

(*b*) Industry;

(*c*) Electricity generation;

(*d*) Agriculture, as to irrigation and also land drainage and flood prevention;

(*e*) Fisheries;

(*f*) Scientific research—e.g. by geophysicists, hydrologists, geologists;

(*g*) Government Departments;

(*h*) River Boards.

5. All the above need enough basic data on *surface water* to enable them to extract the particular type of information in which they are interested. To quote from the Report, "Inland Water Survey", made by the Institution of Civil Engineers dated June, 1942:

> "In the case of surface water, the main object is to obtain particulars of the minimum, average, and maximum quantities of water which flow in rivers and streams and their chemical characteristics.
>
> For example, a knowledge of the minimum flow of a river is essential for determining the amount of water permissible to be extracted for domestic and industrial uses and not necessarily returned to the same stream; it is of special importance for those contemplating the extraction of cooling water, and also for determining the amount of sewage effluent which can be discharged to a river; it is particularly necessary for the correct design of the capacity of impounding reservoirs for water supply, and for water power projects.
>
> The average flow of a river is of special significance for determining the volume of compensation water to be discharged from impounding reservoirs.
>
> The maximum flow is of importance for the correct economic and safe design for overflow weirs of reservoirs coming under the Reservoirs (Safety Provisions) Act, 1930, and is equally important in the design of works for the control of floods."

6. All the bodies and interests mentioned in paragraph 4 need basic data as to the availability of *ground water*. For example, for the accurate ascertainment of variations in the level of the water table, reliable information is needed of the rest level, pumping level and yield of a number of suitably distributed wells, and of the geological strata pierced. It is also important to know the rate of depletion of underground reserves and for this purpose the factors leading to inflows and outflows must be measured. Inflow includes that part of the infiltrated rainfall which is surplus to soil requirements, natural seepage from streams and ponds, leakages from other aquifers and contributions from artificial works. Outflow includes evaporation, flow from springs (including sub-surface flow into rivers and into the sea), seepage into other aquifers, drainage into artificial works and abstraction from wells.

7. All the bodies and interests mentioned in paragraph 4 need basic rainfall data and information on the quality of water.

8. The current activities which contribute information of the nature outlined above are discussed in Section III of this report. The additional work needed to make good deficiencies in the existing information, including publication, is dealt with in Section IV. Section V deals with the third section of our terms of reference. Section VI sets out our conclusions and recommendations. To some extent Sections III, IV and V overlap, as the material does not lend itself to entirely separate handling of the various parts of the terms of reference.

III. CURRENT ACTIVITIES

9. Information relevant to the assessment of water resources may be classified broadly under the heads of rainfall, evaporation, surface water and ground water. Current activities designed to provide information on these matters are described below.

Rainfall

10. The Meteorological Office of the Air Ministry undertakes the collection and processing of observations of rainfall. For general use rainfall information is published annually in "British Rainfall". This gives particulars of annual, seasonal and monthly rainfall and details of rain-days, drought, rain spells, duration and intensity. For the purposes of the Surface Water Surveys a monthly evaluation of the general rainfall is provided in respect of most of the drainage areas of surface water gauging stations for which information is published in the Surface Water Year Book (see paragraphs 22 and 63). The Surface Water Survey Centre of the Ministry of Housing and Local Government, with the advice of the Meteorological Office, is encouraging river boards to undertake schemes of rainfall gauging in accordance with Section 9 of the River Boards Act, 1948, to supplement the general network of rain gauges.

Evaporation

11. There is no convenient standard method of measuring evaporation. Moreover there is a lack of a uniform definition. Various branches of science have different interests in evaporation but each is interested in the rate at which liquid water leaves its "container", whether it be a lake, a plant-cell or a soil pore, and is carried off in the form of vapour. The factors controlling evaporation are mainly meteorological but the physical nature of the water container, through its response or reaction to them, is also involved.

12. The quantitative measurement of evaporation is a matter of great difficulty and cannot be defined in terms which will hold good for all types of containers or surfaces. Many instruments (evaporimeters) have been designed in an attempt to create an artificial container from which evaporation measurements might be made which would be comparable with the actual evaporation from a particular surface or container. It has been found, however, that similar instruments indicate differing amounts of evaporation under similar meteorological conditions. Data from about 16 standard evaporation tanks are published in "British Rainfall" but it is evident that there is lack of harmony between the records.

13. Hence the best that can be done is to make estimates. For assessing the effect of evaporation on river flow, estimates are needed for two main

types of surface: open water (lakes and streams), and land surfaces which may have any kind of vegetation on them or none. Many studies have been made. There has been the theoretical approach based on aerodynamic theory and energy balance theory, and the more practical approach based on a comparison of rainfall with run-off after taking percolation into account. At present it would appear that for extended periods such physical estimates of evaporation are reasonably accurate.

14. Many workers in this field consider that the theoretical method which gives the best practical results is that of Dr. Penman of the Rothamsted Experimental Station. Dr. Penman has combined aerodynamic theory with the energy balance theory to give formulae by means of which evaporation over a period from a water surface can be calculated using four meteorological elements—air temperature, wind speed, hours of sunshine and vapour pressure. Empirical factors, based on experiments at Rothamsted, have been adopted to convert estimates of evaporation from a water surface to those for evapo-transpiration from a soil surface covered with short crops. The method has been applied with fair success by Dr. Penman himself to the assessment of the water balance of the Essex Stour and the Thames Valley above Teddington.

15. Some research on this problem is proceeding within the Meteorological Office. Additionally, at the suggestion of the Hydrological Research Group of the Institution of Water Engineers (on which the Meteorological Office is represented) and with the collaboration of the Metropolitan Water Board, an investigation is being carried out at Kempton Park involving the measurement of changes in level of an unused reservoir, whereby the evaporation losses may be studied.

16. The Meteorological Office is also collaborating with the Fylde Water Board in an investigation at Stocks Reservoir of the yield of the reservoir in relation to meteorological conditions; this involves measurement of the loss from evaporation tanks and of the interception of rainfall by a wood.

Surface Water

17. Surface water is dealt with by the Surface Water Survey Centre of the Ministry of Housing and Local Government, which collects and checks records from surface water gauging stations throughout Great Britain, publishes a selection of these records suitably linked with rainfall evaluations and inspects proposed and established gauging stations in England and Wales.

18. Under the River Boards Act, 1948, river boards have been set up in 32 areas in England and Wales. The terms of the Act also extend for most purposes to the Thames and Lee Conservancy Boards. Section 9 of the Act makes it a duty of river boards to carry out schemes of rainfall and river gauging and 32 out of the 34 boards (including for this purpose the Thames and Lee Conservancy Boards) have submitted outline schemes* of river gauging to the Ministry of Housing and Local Government, after consultation with the Surface Water Survey Centre; the two remaining

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* The general planning of a gauging scheme is described in the "Memorandum on the Survey of a River System" prepared by the Inland Water Survey Committee in 1936.

boards already had satisfactory gauging schemes. The outline schemes, which have all been approved, indicate the proposed distribution of primary gauging stations throughout the areas of the river boards.

19. After approval in principle by the Ministry of Housing and Local Government the river boards are expected to proceed with the schemes in detail. The selection of sites and the choice of the techniques to be adopted is carried out in close liaison with the Surface Water Survey Centre. When each gauging station has been designed and an estimate made of the cost, the river board may apply to the Ministry of Agriculture, Fisheries and Food for a grant towards the cost of construction.

20. When a station is established the calibration may take some time and involve special consideration, and until the Surface Water Survey Centre is satisfied that the measurement and computation of discharges is carried out with care and precision, the records are not accepted for publication. In 1957 records relating to 128 gauging stations were being received by the Surface Water Survey Centre (101 from river boards in England and Wales, and 27 from Scotland). The returns rendered by river boards included 32 from water undertakers.

21. The Surface Water Survey Centre studies, with the Meteorological Office, the mean annual losses (i.e. the difference between mean annual rainfall and surface water run-off) shown by the records received, discussing them where necessary with the Geological Survey. Where discordant results are obtained, it attempts to ascertain the reasons and to eliminate possible causes of error. The frequency of discharges of various magnitudes is also studied. The Centre is thus concerned with the improvement of measuring techniques and the accuracy both of instruments and computations, and to that end advises on the design of flow-measurement stations, makes periodic inspections of existing stations and keeps under review improvements in technique and instrumentation.

22. The Surface Water Survey Centre has published seven Surface Water Year Books dealing with all the 20 years of the period 1935–36 to 1955–56. The information has largely been the result of gaugings, for their own purposes, by various public and private organisations, though the situation is changing owing to the implementation of the River Boards Act, 1948. The latest Year Book, for the period 1955–56, provides information for 128 gauging stations (including Scotland), compared with 116 in the previous edition, including tables of monthly discharges and run-off, together with monthly and long average evaluations of general rainfall. A start has been made on the compilation of water temperature records. No other information on quality of surface water is published centrally, though in their annual reports many river boards publish chemical analyses, usually made in connection with pollution problems.

23. The arrangement of the material in the Surface Water Year Book observes the sequence of the hydrometric areas shown on the key map, numbered and identified by name and number in the list published in the Year Book. The term "hydrometric area" in this report is to be understood in this sense.

For each gauging station the drainage area is given in the Year Book in square miles. The "drainage area" is defined in the explanatory notes as follows:

> "The drainage area of a river gauging station is taken as being the area whose surface directs water towards the river above the gauging station."

The term "drainage area" is used in the same sense in this report.

Ground Water

24. A section of the Geological Survey is responsible for the collection of ground-water information; for example, depth and diameter of wells, strata proved, water levels, yields and quality of water. This collection of data has been assisted in recent years by powers given in the Water Act, 1945, particularly Sections 6 and 7. More than 100,000 wells have now been recorded and this number is being added to at a rate of some 2,000 a year. In addition regional surveys of ground-water resources are being undertaken by the Geological Survey. Publication of records has been suspended for some time and at present a good deal of useful information is not available in published form.

25. The publication by the Geological Survey of a series of County Memoirs, covering counties in the South-East and Midlands of England, began in 1899 and the twenty-eighth memoir was published in 1938. Memoirs contained records of wells sunk and chemical analyses of well waters with, in later volumes, data on rainfall, springs, water levels and yields. Fifty-five war-time pamphlets containing the results of a primary well-survey were issued covering about half the country. The primary well-survey has been completed since the war but the later results have not been published.

26. The Geological Survey is at present carrying out research which includes studies of the movement of water around a pumped well, tracing the direction and rate of movement of ground water, methods of artificial ground-water replenishment and electrical methods of locating and correlating water-bearing strata.

IV. THE ADDITIONAL WORK NEEDED

Rainfall

27. The representations received have not shown any gaps which are not already covered by the plans of the Meteorological Office. We regard these plans as generally satisfactory and the Meteorological Office's future programme is, therefore, outlined below.

28. Hitherto the aim of the Meteorological Office has been to provide estimates of monthly general rainfall for comparison with run-off data for as many drainage areas as possible, especially as a check on the run-off data. The emphasis now is on comparing rainfall and run-off in a general study of the hydrological cycle. For this, more precision in the determination of rainfall as well as of run-off is required. This can be obtained by (i) the thorough inspection of rainfall stations to secure better reports in future and to assess the errors in past reports, (ii) the setting up of an adequate number of rainfall stations in unrepresented areas, (iii) the more accurate determination of snowfall, (iv) the improved measurement of rainfall in

mountainous regions, (v) the detailed study of the general pattern of rainfall over mountainous areas and (vi) the improvement of statistical methods in the determination of general rainfall.

29. The evaluation of rainfall for drainage areas represents a considerable amount of work and the preparation of general monthly rainfall values for over 100 areas is a severe tax on the staff of the rainfall section of the Meteorological Office. The question arises whether continued publication of this information in the Surface Water Year Book is necessary.

30. Rainfall evaluations, together with run-off data, provide a means of comparing the annual losses with the figures for evaporation as computed by the Penman method (see paragraph 14). If a river gauging station has been in operation for a period of years, such comparison also affords a useful check on the accuracy of the rainfall evaluation and river gauging, although the comparison is often complicated by other factors such as changes in ground water storage.

31. Rainfall information is of particular value in the case of small drainage areas. There are many areas at high levels which are important because the high incidence of rainfall on them governs to a large extent the available resources as well as the behaviour of rivers as a whole. The proper assessment for design purposes of storage, yield and compensation water, which has hitherto rested upon a variety of empirical formulae, requires the much surer foundation which can only be provided by a fuller study of rainfall and run-off in such areas. Indeed, in many areas, additional rainfall records are required to enable a detailed comparison to be made.

32. In large areas, particularly where a river gauging station has been in operation for a number of years, the evaluation of rainfall is not quite so important because various combinations of different conditions in different parts of a river basin could produce the same figure for average rainfall. Most other countries, where rivers are on the whole larger than in this country, do not give such information. In the case of a large drainage area, the most useful information is provided by statistical treatment of discharges, in the form of frequency analyses of various kinds.

33. Most of the river gauging stations have not been in existence for long and at the present time the network of primary stations is far from complete. In the majority of cases it would therefore be a loss to omit rainfall data, since it will still be necessary to use rainfall figures in conjunction with river gaugings when information is required about the resources of areas hitherto ungauged. This situation will be gradually remedied as the number of river gauging stations increases.

34. The most practical course therefore would appear to be to retain all the rainfall evaluations for the present, but gradually to drop those for the larger rivers and older gauging stations as time goes on until the tables for most gauging stations on the larger rivers do not include rainfall evaluations. Each case would have to be considered on its merits before a decision could be taken about the need for individual rainfall evaluations.

35. For the smaller drainage areas, where closer study of the rainfall and run-off is undoubtedly required, it will probably be desirable to give rainfall figures for a long time to come. In some reservoired areas an evaluation of

rainfall is made by the water engineer in strict conformity with Meteorological Office practice and it may be possible to arrange for this to be done in other cases so that the figures would be acceptable.

36. Examination of the mean annual loss (rainfall minus run-off) for the eight years 1945–1946 to 1952–1953 for each area shows many discordant results for neighbouring areas. These discordant results may be attributable to differences in storage or to geological factors of percolation out of or into the area, but they may also be due to errors in the measurements at the gauging stations or to insufficient precision in the determination of rainfall. The Meteorological Office could assist in eliminating one of the sources of discrepancy by ensuring increased precision in the determination of area rainfall. It is important therefore to consider in greater detail the various ways, as enumerated in paragraph 28, in which estimates may be made as precise as possible:

(i) Arrangements have been made for the full-time rainfall inspector to inspect some 500–600 rainfall stations a year and so cover existing stations in about ten years, but to reduce this period additional rainfall inspectors would be needed.

(ii) Many river boards have already sought the advice of the Meteorological Office on the siting of rain-gauges and this should continue. (Even with the goodwill of the river boards, however, it may not always be possible to erect rain-gauges where the Meteorological Office would like them, owing to the inaccessibility of the sites and lack of observers.)

(iii) The more accurate recording of snowfall is a difficult matter. There are problems of instrumentation and siting in addition to the inaccessibility of much of the country at high elevations. These problems are receiving the attention of the Meteorological Office and their study should be encouraged, but early solutions are not expected.

(iv) To improve the recording of rainfall in mountainous regions is another difficult matter. Even in mainly level country a rain-gauge only records a fair sample of the rainfall where the mean wind speed does not exceed 10–15 m.p.h. at the rim of the gauge. The erection of a turf-wall round the gauge enables rather more windy sites to be used. The problem of devising ways of recording rainfall in very exposed sites is under investigation by the Meteorological Office, in collaboration with the Road Research Laboratory.

(v) The Meteorological Office also hopes to make a special study of the general pattern of rainfall in mountainous areas. By examining the distribution of rainfall in rugged areas which have a close network of stations it hopes to be able to apply the knowledge so gained to similar areas with few rainfall records.

37. Most rainfall averages quoted in the Surface Water Year Book have been based on the period 1881–1915. Using this period a great deal of background information has been built up which can be used in checking estimates of general rainfall. Most of the reporting stations however for which data were available from 1881 to 1915 no longer exist, or there have been site changes so that records are not immediately comparable with one another.

It has been realised for some time that a new standard period is required and the period 1916-50 has been adopted by the Meteorological Office. The work of preparing new averages for all stations and new and more detailed maps of average rainfall, together with the reassessment of average general rainfall for all the areas in the Surface Water Year Book, is now in hand but will be a big undertaking. Nevertheless it will result in better estimates and will constitute a major contribution to knowledge of the rainfall over the country.

38. Other items to which the Meteorological Office would like to devote further study, given the man-power and facilities, are the statistical determination of extreme rainfall, more useful frequencies (e.g. of dry and wet periods), and the variation of monthly and annual rainfall (including "trends").

39. The Meteorological Office has plans for a detailed study of the variations in time and space of the intensity of rainfall by means of a recording instrument with an open scale and these plans are expected to be in operation soon. Investigations have been started on the artificial stimulation of rainfall.

40. With a view to improving "British Rainfall" a review of the content and layout of this publication was carried out in 1956 in consultation with users of the publication, but no major changes were proposed. However, in the light of experience it is planned to rearrange the publication gradually so that all the rainfall statistics are presented in hydrometric areas, subdivided as and where practicable.

Surface Water—Quantity

41. Representations have been made to the Sub-Committee as follows about additional work considered to be necessary:

(*a*) the number of gauging stations should be increased and water undertakers and other interests should be consulted on the choice of sites for new gauging stations;

(*b*) the gauging of small upland streams should be undertaken;

(*c*) additional information should be collected about small local sources available for general agricultural use or for irrigation, and about the frequency of erosive floods and minimum flows (for the use of fisheries interests);

(*d*) information on all main tributaries of rivers might be included in the Surface Water Year Book;

(*e*) data of the average quantity of water supplied by statutory water undertakers might be collated and published;

(*f*) much of the other information now in the hands of water undertakers should be published and a requirement should be made for the provision of such hydrological data when new schemes for water supply are approved by the Ministry of Housing and Local Government; and

(*g*) the Surface Water Year Book might contain information as to the nature of vegetation in catchment areas.

42. The extent to which the Surface Water Survey can be developed must be related to the financial and manpower resources which are available. It may be that the measurement of a very large number of rivers and streams is desirable, but in the first place it is clearly necessary to establish a network of primary stations on the principal rivers. Until recently there has been no reliable information about the quantity of water discharged by some of the most important rivers in Great Britain, and indeed that is still the position in some cases. The logical development of the Survey is to measure, first, the discharge of the main river in each basin and then to analyse the components of the discharge by measuring the tributaries and sub-tributaries. As this work develops, it will undoubtedly be found that a point is reached where the behaviour of adjacent or similar streams can be assumed to be so much the same that it would be unrewarding to measure them all.

43. Present plans for the Survey are that, with the co-operation of the river boards, the number of primary gauging stations should be increased to about 400, covering all parts of river systems.* At the same time the voluntary co-operation of water undertakers is being sought with a view to obtaining complete hydrometric records from as many reservoired areas as possible. The first and most urgent task is the completion of the network of primary river gauging stations. When this has been done it will be possible to proceed to the study of particular areas or specific problems by the establishment, where necessary, of secondary gauging stations.

44. All river boards have now submitted outline gauging schemes to the Ministry of Housing and Local Government but of the 400 primary gauging stations proposed less than one third are as yet in operation. We consider it important that vigorous action should be taken to set up the remainder within the next two to three years.

45. In addition to the establishment of primary gauging stations, the Surface Water Survey Centre encourages the gauging of smaller streams and the collection of data, even when the information is not complete or not of an accuracy comparable with published data. Much remains to be done in extending this work and ensuring that the information is available in such a form and in such units of measurement as will make it readily comparable with other records and hence of greater value.

46. It will be seen, with regard to the specific points mentioned in paragraph 41 above, that (*a*), (*b*) and (*d*) will largely be met by plans now in hand. On (*a*), however, we recommend that arrangements should be made for interests with a legitimate concern to have access to the outline river gauging schemes at the offices of the river boards or at the Ministry of Housing and Local Government and that their views on the siting of gauges should be taken into account at the formative stage. On (*c*) it is thought that these points are largely local in significance and that there is no need to enlarge upon the national Surface Water Survey as at present planned and developing. Information as at (*e*) is already published in the Water Engineer's Handbook.† On (*f*) we understand that the Ministry of Housing and Local Government are making administrative arrangements to obtain hydrological data from public water undertakers in respect of new water schemes being approved.

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* See paragraphs 18–20 for the procedure for establishing a gauging station.

† Published annually by The Colliery Guardian Co., Ltd.

This may make it unnecessary to impose a requirement that such data should be supplied, but if it does not we consider that further powers should be sought. With regard to earlier schemes, we understand that some information has been collected by the Surface Water Survey Centre but is of varying reliability. We consider that publication would not be worthwhile, and that the existing arrangements under which the information is freely available to properly authenticated enquirers should meet the case. On (*g*) we consider that it is not feasible at the present time to obtain information on the vegetation of all catchment areas.

47. Additional work is needed to improve measuring techniques and the accuracy both of measuring instruments and of computations. Laboratory work is being undertaken by various bodies with a view to establishing how the discharge of weirs of a certain profile or flumes of a certain design may be calculated, but the Surface Water Survey Centre does not consider that theoretical calibration should be relied upon unless supplemented by current-meter observations on the site. The Flow Measurement Committee of the British Standards Institution is at present working on a Code of Practice covering all aspects of the measurement of flow in open channels.

48. Current-meters can be relied upon to give consistent results provided the proper technique is employed and the instruments themselves have been calibrated in a rating tank. There is as yet no specially constructed rating tank in this country, but two organisations possess ship tanks which are available for this purpose, namely the National Physical Laboratory at Teddington and Messrs. Saunders Roe, Isle of Wight. The Surface Water Survey Centre has examined both these installations and has agreed upon a standard form of test for current-meter calibrations which can be carried out at either place. A current-meter rating tank is now under construction at the Hydraulics Research Station, Wallingford (Department of Scientific and Industrial Research), which river boards and other authorities may be able to use when it becomes available in 1959 or 1960. There is a need for current-meters in use to be re-calibrated more frequently and for the maintenance, condition and design of these instruments to be kept under constant review.

Surface Water—Quality

49. Temperature may for convenience be dealt with here as a quality of water. With the increasing use of cooling water, information about temperature is becoming more important. The Surface Water Survey Centre is encouraging river boards to collect and record " natural " water temperatures (i.e. in unpolluted rivers and streams) and two river boards are maintaining such records in a continuous and systematic way. The Survey Centre proposes to encourage the establishment of a limited number of natural temperature locations, possibly not more than 50. In all these the method used and the computation of results will follow the same practice and will be comparable one with another. We understand that certain researches into the fluctuation of river water temperatures are being carried out by the Water Pollution Research Board and that the Survey Centre will keep methods of observation under review in the light of the results.

50. The other aspects of quality may be divided into natural quality (content of mineral salts and silt) and modified quality (in relation to pollution).

The majority of analyses carried out by river boards deal with the second category, but the need is felt by many users for information on both aspects. For these, an adequate quality survey would need to cover both categories, as well as temperature and, since quality depends on flow, analysis of numerous samples taken at each point tested would be required.

51. A quantity survey has a permanent value. A knowledge of flows in past years is of more than historical interest; it enables present flows to be interpreted more accurately. The accumulation of records over a number of years is therefore very desirable. This is not true of quality to the same degree. Over the years the amount of polluting matter present may greatly increase, owing to the establishment of new towns and industries, or it may greatly decrease, owing to better purification of effluents. A continuous record of quality certainly provides a history of pollution, but to anyone interested in using the water the information obtained several years ago may be valueless. On this account the case for central publication in permanent form of information on quality is less strong than that for publishing information on quantity.

52. We should regard it as sufficient, for the time being at least, if river boards (*a*) published in their Annual Reports lists of places where samples of river water were regularly taken for analysis and (*b*) included in the analyses of a representative proportion of these samples, in addition to the determinations required for their own purposes, particulars of temperature (other than at the approved stations referred to in paragraph 49), total dissolved solids, hardness (carbonate and non-carbonate), alkalinity, chloride and sulphate. Several river boards already carry out at least some of these determinations as a matter of routine. We also recommend publication of the analyses, or averages and extremes of them, where this is reasonably practicable. River boards should not be expected to undertake special analyses of water; these should be the responsibility of the body requiring them.

Ground Water—Quantity

53. Representations made to the Sub-Committee have been largely concerned with non-publication rather than with the lack of specific information.

54. It has been suggested that the Geological Memoirs are due for revision and that the hydrological data now being collected by the Geological Survey, in part as agents of the Ministry of Housing and Local Government under the provisions of the Water Act, 1945, should be published. In view of the importance of the data we emphasise that this should be done, subject to any necessary safeguards for information provided in confidence. Water undertakers have stressed the value of hydrogeological surveys of aquifers to give an appreciation of the availability of water and its quality. This is covered by the regional surveys now being undertaken by the Geological Survey (paragraph 24), which, however, have not as yet been published.

55. As regards specific information we consider that the scant records of the flow of ground water from springs should be supplemented, since such information is essential to accurate estimation of the ground-water storage equation. We suggest that the Geological Survey, in collaboration with the Surface Water Survey Centre, should consider extending its activities in

this direction and that water undertakers, river boards and others who measure spring flows should provide such information wherever possible.

56. We consider that, in addition to those measurements already taken and collected, there is a need for frequent, regular and widespread measurement of levels in a number of carefully chosen wells or boreholes, supplemented by records of water level fluctuations made on automatic water stage recorders. We suggest that the Geological Survey should consider the use of voluntary workers for this purpose, as is done by the Meteorological Office in the recording of rainfall.

57. The artificial recharge of aquifers may, at some stage, be practised in this country. If there is legislation on this we recommend that it should contain powers to require that the quantity and quality of water returned to the ground should be measured and that records should be kept and made available for inspection.

Ground Water—Quality

58. We consider that more information should be collected and made available about the quality of ground water. The Water Abstraction Regulations, 1947*, made under Section 6 of the Water Act, 1945, enable the Minister of Housing and Local Government to require well-owners to make analyses of water abstracted and to furnish copies of such analyses to the Minister. We understand that these powers are being used to collect information in cases where analyses are known to have been carried out and that the Geological Survey expect this to give representative samples which, together with analyses which they themselves undertake, should for the time being be sufficient to indicate the quality of water in the strata concerned. As the Geological Survey propose to use the information in their publications, we make no further recommendation at this stage.

V. COLLECTION, INTERPRETATION, CORRELATION AND PUBLICATION OF INFORMATION

59. (i) Our inquiries elicited few specific criticisms of the present arrangements. We feel however that progress in the collection of hydrological information would be assisted by greater knowledge of the uses to which it is put and by a greater measure of co-ordination in the activities of the organisations concerned. We are also conscious that within the field covered by our inquiries there is a continuing need for research into measuring techniques and into the accuracy of measuring instruments and the coverage of measurements generally—for example with regard to floods and other extreme conditions.

(ii) In looking into the arrangements for the collection and interpretation of information we have had to consider the purposes for which hydrological information is required and this has led us inevitably to pay some regard to the question of hydrological relationships. In addition to those mentioned in paragraphs 15, 16, 26 and 49 examples of research which have been cited are:

(*a*) studies of the water balance in a number of areas;

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* S.R. & O. 1947, No. 2342; H.M. Stationery Office.

(*b*) studies of the assessment of evaporation over an area ;

(*c*) studies of the effect of afforestation and other forms of vegetation on water resources.

(iii) We therefore *recommend* that steps should be taken (*a*) to review generally the work at present being done on hydrological research and (*b*) to determine how this work should be co-ordinated and what extensions or modifications appear to be desirable.

60. *Collection of information.* As described in Parts III and IV of this report, the collection of information is carried out by the following agencies:

(i) *Rainfall and evaporation*

The Meteorological Office, with the co-operation of river boards, public water undertakers, voluntary workers and others.

(ii) *Surface Water*

The Surface Water Survey Centre, with the co-operation of river boards, public water undertakers and others.

(iii) *Ground Water*

The Geological Survey, with the co-operation of public, industrial, agricultural and other well-owners, voluntary workers and others.

We at present *recommend* only minor extensions of these activities, as set out in the body of the report and summarised in Part VI.

61. *Interpretation of information.* The bodies and interests using the information dealt with in this report interpret it according to their needs and, subject to what is said in paragraph 59, we make no recommendation.

62. *Correlation of information.* We *recommend* that to facilitate the correlation of hydrological information and thereby enhance the value to users of such information all data should be presented on a common basis of river basin areas. This basis is already followed for surface water and is, we are informed, to be adopted for rainfall. We understand that although its use for ground water raises complications, nevertheless the Geological Survey are exploring the possibilities of its adoption.

63. *Publication of information.* A list of the principal official publications containing information on water, with a résumé of the contents and proposals for the future (where known), is given in Appendix I. Our views on these proposals and suggestions for further publication are summarised as follows:

(i) *"British Rainfall"*

The Meteorological Office plan to re-arrange the contents and layout of this publication so that the information will relate to hydrometric areas. We endorse this proposal, while noting that future plans include the study of such subjects as the more extensive recording of rainfall in mountainous regions, the amount and effects of snow accumulation, the more accurate determination of evaporation (in collaboration with other interests), the re-numbering of all rainfall stations by means of the grid system and by hydrometric areas, and the revision of the tabulation of rainfall data so as to facilitate machine-processing and the development of statistical methods.

(ii) *Surface Water Year Book*

We endorse the present content of the Year Book, which provides monthly analyses of discharge, run-off and related rainfall in respect of rivers and streams, and we note with approval that a master record of mean daily discharges is available for inspection. In the future it is proposed that the Year Book shall include data from many more river gauging stations, abbreviated records of small reservoired areas and more records of water temperature. A selection of frequency tables will be published when individual river gauging stations have been in existence long enough to justify them. We approve these proposals. We are also satisfied that the plans of the Surface Water Survey Centre and of the Meteorological Office are developing along the right lines and with adequate co-operation between the two.

(iii) *Quality of Surface Water*

We *recommend* that river boards should include in their annual reports lists of places where samples are regularly taken for analysis and, where reasonably practicable, publish the analyses taken or averages and extremes of them.

(iv) *Ground Water*

We *recommend* that, in view of the widespread demand for information on ground water, the Geological Survey should resume publication of the information they collect at an early date.*

(v) *Quality of Ground Water*

We note that the Geological Survey expect to obtain sufficient information for a reliable analysis of quality of water in the various strata and that the results will be published.

(vi) *Bibliography*

Hydrological bibliographies have been issued in some countries but there is no corresponding British publication. In view of the important contribution which has been made to hydrological knowledge by British engineers and scientists, we *recommend* that a list of the more important works should be compiled for publication.

VI. CONCLUSIONS AND RECOMMENDATIONS

64. We consider that there is a need for further investigation into hydrological relationships and for further inquiry into the uses of hydrological information generally, and we *recommend* that steps be taken to review the work at present being done on hydrological research and to determine how such work should be co-ordinated and what extensions or modifications may be desirable (paragraph 59).

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* We now understand that plans for publication are in hand.

65. We conclude, after studying the representations made to us, that existing or proposed arrangements for the collection and interpretation of information, as described in the report, broadly meet the known need, although we recommend certain extensions of these activities, namely:

(i) the more frequent inspection of rainfall stations (paragraph 36 (i));

(ii) the more accurate recording of snowfall (paragraph 36 (iii));

(iii) further recording in connection with ground water (paragraphs 55 and 56).

Less than one-third of the proposed primary river gauging stations are as yet in operation, however, and we *recommend* that vigorous action be taken to set up the remainder within the next two to three years (paragraph 44).

We also *recommend* that bodies with a legitimate interest should have access to outline river gauging schemes and that their views as to the siting of gauges should be taken into account at the formative stage (paragraph 46).

66. To facilitate the correlation of hydrological information and thereby enhance the value to users of such information we *recommend* that data on rainfall, surface water, and ground water should be presented on a common basis of river basin areas (paragraph 62).

67. *On publication:*

(*a*) We endorse the planned future content of " British Rainfall " and the Surface Water Year Book (paragraph 63).

(*b*) With regard to the quality of surface water, we *recommend* that river boards should publish lists of places where samples are regularly taken for analysis and also, where reasonably practicable, the analyses taken, or averages and extremes of them (paragraphs 52 and 63).

(*c*) We *recommend* that the Geological Survey should resume publication of information on ground water (paragraphs 54 and 63).*

68. If there is legislation affecting the artificial recharge of aquifers, we recommend that it should contain provisions requiring that the quantity and quality of water returned to the ground should be measured and that records should be kept and be made available for inspection (paragraph 57).

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* See footnote to page 15.

69. Our investigations have made large demands on the Secretaries and on the Assessors from the Ministries concerned. We wish, finally, to express our sense of indebtedness to the Secretary, Miss M. E. Petzsche, to the Assistant Secretaries, first Mr. G. D. Vaughan and later Mr. J. W. Storr, and to the Assessors who have so readily placed their knowledge at our disposal.

J. PROUDMAN.

ALAN ATKINSON.

D. CLARK.

JOHN COCKRAM.

G. E. FITZHUGH.

JOHN GODMAN.

C. J. JACKSON.

W. B. R. KING.

W. C. KNILL.

HUGH G. RAMSAY.

J. I. TAYLOR.

E. W. WELLS.

M. E. PETZSCHE, *Secretary.*

J. W. STORR, *Assistant Secretary.*

December, 1958.

APPENDIX I

PRINCIPAL OFFICIAL PUBLICATIONS

*" British Rainfall "**

Summaries of rainfall data collected by the Meteorological Office are published in the annual volumes of " British Rainfall " which form a continuous series beginning in 1861.

Each volume contains a general table of total rainfall for the year in which are listed all the stations with records considered sufficiently reliable for publication. For each station brief notes are given about the site and equipment together with the total rainfall recorded during the calendar year. In addition to the general table, there is a series of articles, with numerous tables and maps, summarising the rainfall of the year in various ways and drawing attention to outstanding and important characteristics. One of the articles deals with seasonal rainfall, taking the winter six months and the summer six months separately. The different articles are intended to provide useful information or guidance for users with particular interests. Thus the discussion of droughts and dry spells is written with agricultural and water supply interests in mind, while the discussion of heavy falls is relevant to problems of drainage and floods.

" British Rainfall " each year contains some material, with discussion, about evaporation and percolation. Not much information is available, but it is hoped that in future years it will be possible to extend and develop this side of the work.

It would not be practicable to publish all the information received by the Meteorological Office. An important feature of " British Rainfall " therefore is that it serves as an index and guide to the much fuller information which is available for consultation at the Meteorological Office.

*The Daily Weather Report**

The Daily Weather Report gives daily values of rainfall for the periods 09 hours-21 hours and 21 hours-09 hours for 50 to 60 well distributed stations in the British Isles. A monthly summary of the Daily Weather Report gives for 20 representative stations the total rainfall for the month (both in amount and as a percentage of average), the number of days of rainfall and the maximum fall in a day, together with the highest and lowest totals on record.

*The Monthly Weather Report**

The Monthly Weather Report gives a detailed description of the weather during the month with a special paragraph on precipitation, and includes a map showing the distribution of total rainfall during the month over the United Kingdom and Northern Ireland. It also gives monthly totals of rainfall (both in amount and as a percentage of average) and the maximum fall in a day for nearly 500 stations. An annual summary of the Monthly Weather Report gives the values (as a percentage of average) of the annual rainfall amount and the number of days different from the average for ten districts of the United Kingdom and Northern Ireland.

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* Published by H.M. Stationery Office

*Surface Water Year Book**

In the first two Year Books (1935–36 and 1936–37) daily mean discharges, from which all other categories of flow can be computed, were quoted for nearly all stations, and only brief monthly analyses were given.

In the first post-war Year Book (1953–54) to cover a single water year, similar information was included (but for a larger number of stations) together with average and extreme discharges for each month, and calculations of run-off and general rainfall. To continue to include all this information for each station would result in volumes of excessive size and expense.

The latest edition, for 1955–56, contains monthly analyses of 128 gauging stations throughout Great Britain, showing discharges and (for most stations) rainfall and run-off. A table showing the duration of flows of various magnitudes (discharge frequencies) for selected stations, and two records of natural water temperatures are also included. A separate table sets out discharges, rainfall and run-off for selected reservoired areas.

Eventually it is hoped that the Year Book will contain information for at least 400 gauging stations. If a volume of moderate size and reasonable cost is to be offered for sale, a limit must be placed on the amount of information included per gauging station.

A choice has to be made between including the daily mean discharges and the monthly analyses. The Surface Water Survey Centre have obtained opinions from hydrologists, consulting engineers, water engineers, river board engineers, pollution officers and others. The consensus of opinion is that if economy dictates a choice the monthly analyses should be retained, details of daily mean discharges being obtained from the Survey Centre or the measuring authority concerned.

Annual Reports of River Boards

The form reports should take is laid down by direction† of the responsible Ministers under Section 12 of the River Boards Act, 1948, although river boards are not precluded from adding any further information they consider appropriate. The prescribed information includes:

(*a*) on water resources—
  (i) particulars of stations measuring rainfall and the characteristics of rivers and streams;
  (ii) the places where records of measurements are held available for inspection;
  (iii) actions taken to obtain information as to abstractions of water;
  (iv) brief general discussion of rainfall and river flow in the river board area during the 12 months under review;

(*b*) on prevention of river pollution—
  (i) brief appreciation of the quality of water in the rivers and more important streams, together with analyses and more detailed notes if desired;
  (ii) information about effluents, action to remedy pollution, and any important research undertaken on pollution.

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* Published by H.M. Stationery Office.

† "Form of Annual Report of River Boards," published by H.M. Stationery Office.

APPENDIX II

LIST OF AUTHORITIES AND ORGANISATIONS FROM WHICH EVIDENCE WAS RECEIVED

1. Atomic Energy Authority.
2. British Waterworks Association.
3. Central Electricity Generating Board.
4. Federation of British Industries.
5. Gas Council.
6. Institute of British Geographers.
7. National Coal Board.
8. Royal Society.
9. Geological Survey.
10. Meteorological Office.
11. Surface Water Survey Centre.
12. Ministry of Agriculture, Fisheries and Food.
13. Ministry of Housing and Local Government.
14. Ministry of Supply.

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